TRANSMISSIVE SCREEN AND REAR PROJECTOR

BACKGROUND OF THE INVENTION

1. Field of Invention

[0001] The present invention relates to transmissive screens and rear projectors.

2. Description of Related Art

[0002] Demands for rear projectors have been growing as displays suitable for, for example, home theater monitors and wide-screen television sets.

[0003] Fig. 10 illustrates the optical system of a rear projector. This rear projector 14, as shown in Fig. 10, has a housing 50 including an optical projecting unit 20 for projecting an image, a light-guide mirror 30 for guiding the image projected by the optical projecting unit 20, and a transmissive screen 42 on which the image guided by the light-guide mirror 30 is projected.

[0004] This rear projector 14 particularly requires a transmissive screen 42 with wider viewing angle characteristics. Patent document 1 discloses such a transmissive screen with wider viewing angle characteristics. Fig. 11 is a sectional view of the transmissive screen. This transmissive screen 800, as shown in Fig. 11, includes a Fresnel lens portion 810 having Fresnel lens components on its light-exiting surface, a microlens array portion 820 disposed at the light-exiting surface side of the Fresnel lens portion 810 and having many microlenses 820a on its light-incident surface, a light shield portion 840 disposed at the light-exiting surface side of the microlens array portion 820, and a diffusing sheet 850 disposed at the light-exiting surface side of the light shield portion 840.

[0005] Figs. 12 to 14 illustrate the structures of microlenses disclosed in Patent document 1. Fig. 12 shows rhombic microlenses; Fig. 13 shows a combination of rhombic microlenses and a hexagonal microlens; and Fig. 14 shows rectangular microlenses. In Figs. 12 to 14, each (a) is a front view of the light-incident surfaces of these microlenses, while each (b) is a front view of the light-exiting surfaces of these microlenses; apertures 840a are arranged in the light shield portion 840, as shown in these drawings.

[0006] Patent document 2 also discloses such a transmissive screen with wider viewing angle characteristics. Fig. 15 is a perspective view of the transmissive screen. This transmissive screen 900, as shown in Fig. 15, has many spherical light-diffusing particles 920a arrayed vertically and horizontally. The light-diffusing particles 920a diffuse image light incident on the transmissive screen 900 to emit.

[0007] The above transmissive screens 800 and 900 have the advantage of better vertical viewing angle characteristics over known transmissive screens using lenticular lenses. This advantage is derived from the refraction of the microlenses 820a or the light-diffusing particles 920a.

[0008] Japanese Unexamined Patent Application Publication No. 2000-131506 (Figs. 1 to 5).

[0009] Japanese Unexamined Patent Application Publication No. 2001-133888 (Figs. 3 and 4).

[0010] However, there is a need for a well-balanced increase in the vertical, horizontal, and oblique viewing angle characteristics in order to enhance the viewing angle characteristics for the above transmissive screens 800 and 900.

[0011] Accordingly, an object of the present invention is to provide a transmissive screen allowing a well-balanced increase in the vertical, horizontal, and oblique viewing angle characteristics for enhancing the viewing angle characteristics, and a rear projector including such an excellent transmissive screen.

SUMMARY OF THE INVENTION

[0012] As a result of intensive efforts to achieve the above object, the inventors of the present invention have found the possibility of a well-balanced increase in the vertical, horizontal, and oblique viewing angle characteristics to enhance the viewing angle characteristics by arraying microlenses vertically and horizontally in such a way that adjacent microlenses have common sides and rotating the array by 45°, thereby completing the present invention.

[0013] (1) A transmissive screen according to the present invention includes a Fresnel lens portion having Fresnel lens components on its light-exiting surface; and a microlens array portion disposed at the light-exiting surface side of the Fresnel lens portion and having many microlenses on its light-incident surface. The microlens array portion has the microlenses arrayed vertically and horizontally such that adjacent microlenses have common sides and the array is rotated by 45°.

[0014] According to the transmissive screen of the present invention, the microlens array portion, in which adjacent microlenses have common sides, can eliminate or reduce non-lens regions, which may exist in the spaces between the microlenses. As a result, the microlenses of the microlens array portion can have a larger effective area to enhance the light diffusion efficiency.

[0015] As described above, the microlens array is rotated by 45° in the transmissive screen of the present invention. The microlens array, when assembled in the transmissive screen, has larger array pitches in the vertical and horizontal directions of the transmissive screen compared when it is not rotated, permitting a larger vertical and horizontal entrance pupil in each microlens. Thus, each microlens peripheral region (which is absent in the oblique directions of the screen) provides a higher refraction to generate sufficient light diffusion in the vertical and horizontal directions of the screen. The refraction of each microlens also provides a certain amount of light diffusion in the oblique directions of the screen.

[0016] As a result, the transmissive screen provides a well-balanced increase in the vertical, horizontal, and oblique viewing angle characteristics to enhance the viewing angle characteristics.

[0017] (2) In the transmissive screen according to (1), the microlenses preferably have larger vertical and horizontal array pitches than oblique array pitches at an angle of 45°.

[0018] In such a structure, each microlens provides higher refraction in the vertical and horizontal directions of the transmissive screen than in the oblique directions of the transmissive screen to generate sufficient light diffusion. This transmissive screen, therefore, ensures viewing angle characteristics required for transmissive screens to provide higher light diffusion in the vertical and horizontal direction of the transmissive screen than in the oblique directions of the transmissive screen.

[0019] (3) In the transmissive screen according to (1) or (2), the microlenses preferably range from 10 to 150 μm in diameter.

[0020] The microlenses are set to 150 μm or less in diameter because the resolution decreases for excessively large microlenses relative to pixels projected on the transmissive screen. From this point of view, the microlenses are more preferably 100 μm or less and most preferably 80 μm or less in diameter. On the other hand, the microlenses are set to 10 μm or more in diameter for the sake of simplicity of manufacture. From this point of view, the microlenses are more preferably 20 μm or more and most preferably 30 μm or more in diameter.

[0021] The diameter herein indicates that of microlenses isolated from each other, that is, arrayed in such a way that adjacent microlenses do not have common sides.

[0022] (4) The transmissive screen according to (1) or (2) preferably further includes a light diffusing portion disposed between the Fresnel lens portion and the microlens array portion.

[0023] In such a structure, the light diffusing portion decreases the regularity of light incident on each microlens (in, for example, intensity, angle, and phase) to suppress the generation of light diffraction in the microlens array portion effectively.

[0024] In addition, since the light diffusing portion diffuses light passing through the Fresnel lens portion, and then the light enters the microlens array portion, the generation of a regular interference pattern can be suppressed, leading to effectively suppress moire fringing in the Fresnel lens portion and the microlens array portion.

[0025] (5) The transmissive screen according to one of (1) to (3) preferably further includes a diffusing sheet disposed at the light-exiting surface side of the microlens array portion.

[0026] In such a structure, the diffusing sheet can convert light passing through the microlenses into light with specific viewing angle characteristics.

[0027] (6) The transmissive screen according to (5) preferably further includes a light shield member disposed between the microlens array portion and the diffusing sheet. The light shield member has apertures near focal points of the microlenses.

[0028] In such a structure, the light shield member can suppress the reflection of external light effectively, thus increasing image contrast.

[0029] (7) A rear projector according to the present invention includes an optical projecting unit and a transmissive screen according to one of (1) to (6).

[0030] The transmissive screen in the rear projector allows a well-balanced increase in the vertical, horizontal, and oblique viewing angle characteristics to enhance the viewing angle characteristics. The present invention, therefore, provides an excellent rear projector having better viewing angle characteristics with a well-balanced increase in vertical, horizontal, and oblique viewing angle characteristics.

BRIEF DESCRIPTION OF THE DRAWINGS

[0031] The invention will be described with reference to the accompanying drawings, wherein like numerals reference like elements, and wherein:

[0032] Fig. 1 illustrates the structure of a transmissive screen according to a first embodiment of the present invention.

[0033] Fig. 2 illustrates the structure of the transmissive screen according to the first embodiment of the present invention.

[0034] Fig. 3 illustrates the structure of a transmissive screen according to a comparative embodiment of the present invention.

[0035] Fig. 4 shows the viewing angle characteristics of the transmissive screen according to the first embodiment of the present invention.

[0036] Fig. 5 is a sectional view of a transmissive screen according to a second embodiment of the present invention.

[0037] Fig. 6 is a sectional view of a transmissive screen according to a third embodiment of the present invention.

[0038] Fig. 7 is an external view of a rear projector according to a fourth embodiment of the present invention.

[0039] Fig. 8 illustrates the optical system of the rear projector according to the fourth embodiment of the present invention.

[0040] Fig. 9 illustrates the optical system of a rear projector according to a fifth embodiment of the present invention.

[0041] Fig. 10 illustrates the optical system of a known rear projector.

[0042] Fig. 11 is a sectional view of the known transmissive screen.

[0043] Fig. 12 is a plan view of the known transmissive screen.

[0044] Fig. 13 is a plan view of the known transmissive screen.

[0045] Fig. 14 is a plan view of the known transmissive screen.

[0046] Fig. 15 is a perspective view of another known transmissive screen.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0047] Embodiments according to the present invention will now be described by means of the attached drawings.

[0048] (First Embodiment)

[0049] Fig. 1 illustrates the structure of a transmissive screen according to a first embodiment. Fig. 1(a) is a sectional view of the transmissive screen according to the first embodiment. Fig. 1(b) is an SEM photograph of a surface of a microlens array portion in the first embodiment. Fig. 2 also illustrates the structure of the transmissive screen according to the first embodiment.

[0050] Fig. 2(a) is a plan view of a surface structure of the microlens array portion according to the first embodiment. Figs. 2(b), 2(c), and 2(d) are sectional views taken along lines A-A', B-B', and C-C', respectively, in Fig. 2(a).

[0051] Referring to Figs. 1 and 2, this transmissive screen 100 includes a Fresnel lens portion 110 having Fresnel lens components on its light-exiting surface and a microlens array portion 120 disposed at the light-exiting surface side of the Fresnel lens portion 110 and having many microlenses 120a on its light-incident surface. The microlens array portion 120 has a structure in which the microlenses 120a are arrayed vertically and horizontally such that adjacent microlenses 120a have common sides and the microlens array portion 120 is rotated by 45°.

[0052] According to the transmissive screen 100, therefore, the microlens array portion 120 in which adjacent microlenses 120a have common sides can eliminate or reduce non-lens regions Q, which may exist in the spaces between the microlenses 120a. As a result, the microlenses 120a of the microlens array portion 120 can have a larger effective area to enhance the light diffusion efficiency.

[0053] As described above, the microlens array portion 120 is rotated by 45° in the transmissive screen 100. The microlens array portion 120, when assembled in the transmissive screen 100, has larger array pitches in the vertical and horizontal directions (VH directions) of the transmissive screen 100 compared when it is not rotated, permitting a larger vertical and horizontal (VH directional) entrance pupil in each microlens 120a. Thus, each microlens peripheral region P (which is absent in the oblique directions of the screen) provides a higher refraction to generate sufficient light diffusion in the vertical and horizontal directions (VH directions) of the transmissive screen 100. On the other hand, the refraction of each microlens 120a also provides a certain amount of light diffusion in the oblique directions (XY directions) of the transmissive screen 100.

[0054] As a result, the transmissive screen 100 provides a well-balanced increase in the vertical, horizontal, and oblique viewing angle characteristics to enhance the viewing angle characteristics.

[0055] In the transmissive screen 100 according to the first embodiment, the microlenses 120a have larger array pitches (d3 and d4) in the vertical and horizontal directions (VH directions) than those (d1 and d2) in the oblique directions (XY directions) at an angle of 45°.

[0056] Each microlenses 120a provides higher refraction in the vertical and horizontal directions (VH directions) of the transmissive screen 100 than in the oblique directions (XY directions) of the transmissive screen 100 to generate sufficient light diffusion. This transmissive screen 100, therefore, ensures viewing angle characteristics required for transmissive screens to generate higher diffusion in the vertical and horizontal directions (VH directions) of the transmissive screen than in the oblique directions (XY directions) of the transmissive screen.

[0057] These microlenses 120a may be arrayed more densely in the X and Y directions to eliminate the non-lens regions Q which may exist in the spaces between adjacent microlenses 120a in the vertical and horizontal directions (VH directions) of the screen. This arrangement can improve the light usage and provide more desirable viewing angle characteristics for transmissive screens of rear projectors.

[0058] The microlenses for the microlens array portion 120 are 40 μm in diameter. These microlenses avoids deterioration of the display quality attributed to a decreased resolution. These microlenses, arrayed vertically and horizontally with no space in the microlens array portion 120, have vertical and horizontal array pitches of 30 μm or less.

[0059] In the transmissive screen 100 according to the first embodiment, the microlens array portion 120 has a structure in which the microlenses 120a are arrayed vertically and horizontally such that adjacent microlenses 120a have common sides and the microlens array portion 120 is rotated by 45°, although the microlens array portion 120 may have another structure, such as that shown in Fig. 3.

[0060] Fig. 3 illustrates the structure of a transmissive screen according to a comparative embodiment. Fig. 3(a) is a plan view of a surface structure of a microlens array portion according to the comparative embodiment. Figs. 3(b), 3(c), and 3(d) are sectional views taken along lines A-A', B-B', and C-C', respectively, in Fig. 3(a).

[0061] As shown in Fig. 3, this microlens array portion has a structure in which microlenses are arrayed in a honeycomb pattern such that adjacent microlenses have common sides. Thus, the transmissive screen according to the comparative embodiment, having the microlens array portion in which adjacent microlenses have common sides, can also eliminate or reduce non-lens regions Q, which may exist the spaces between the microlenses. As a result, the microlenses of the microlens array portion can have a larger effective area to enhance the light diffusion efficiency.

[0062] However, in the transmissive screen according to the comparative embodiment, as shown in Figs. 3(b) to 3(d), the microlenses have a smaller array pitch d5 in the horizontal direction (H direction) of the transmissive screen than that of the transmissive screen 100 according to the first embodiment, thus not allowing a larger entrance pupil in the horizontal direction (H direction) of the transmissive screen in each microlens. On the other hand, in the vertical direction (V direction) of the transmissive screen, the microlenses have a larger array pitch d6 than that of the transmissive screen 100 according to the first embodiment, providing a larger entrance pupil in the vertical direction (V direction) of the transmissive screen in each microlens. In this case, however, the array pitch d6 of the microlenses in the vertical direction (V direction) of the transmissive screen is so large as to decrease the resolution of a projected image.

[0063] Therefore, the transmissive screen according to the comparative embodiment has difficulty in providing a well-balanced increase in the vertical, horizontal, and oblique viewing angle characteristics to enhance viewing angle characteristics and has the drawback of a decreased resolution of a projected image.

[0064] On the other hand, the transmissive screen 100 according to the first embodiment is free from such a drawback and provides a well-balanced increase, on the whole, in the vertical, horizontal, and oblique viewing angle characteristics to enhance the viewing angle characteristics.

[0065] Fig. 4 illustrates the viewing angle characteristics of the transmissive screen 100 according to the first embodiment of the present invention. In Fig. 4, A represents the viewing angle characteristics of the transmissive screen 100 according to the first embodiment, and B represents the viewing angle characteristics of the transmissive screen according to the comparative embodiment. Fig. 4 shows that the transmissive screen 100 according to the first embodiment has better viewing angle characteristics than the transmissive screen according to the comparative embodiment.

[0066] (Second Embodiment)

[0067] Fig. 5 illustrates the structure of a transmissive screen according to a second embodiment. As shown in Fig. 5, the transmissive screen 200 according to the second embodiment includes a Fresnel lens portion 210, a microlens array portion 220, and a light diffusing portion 230 disposed between the Fresnel lens portion 210 and the microlens array portion 220.

[0068] This light diffusing portion 230 decreases the regularity of light incident on each microlens (in, for example, intensity, angle, and phase) to suppress the generation of light diffraction in the microlens array portion 220 effectively.

[0069] The light diffusing portion 230, disposed between the Fresnel lens portion 210 and the microlens array portion 220, diffuses light passing through the Fresnel lens, and then the light enters the microlens array portion 220. This process suppresses a regular interference pattern, leading to effectively suppress moire fringing generated in the Fresnel lens portion 210 and the microlens array portion 220.

[0070] In the transmissive screen 200 according to the second embodiment, the light diffusing portion 230 is a resin sheet of a so-called surface light diffusing type having one rough surface (which diffuses light substantially at its surface). Since light diffusion occurs at the surface of the resin sheet, it can exhibit the light diffusion function even if the thickness is decreased. This advantage permits a shorter distance between the Fresnel lens portion 210 and the microlens array portion 220, thus minimizing the generation of ghost images attributed to internal diffusion and decreases both in contrast and transmittance. This resin sheet is manufactured by transferring a rough surface, formed by sandblasting, of a metallic mold to a resin sheet through casting or extrusion. Thus, a light diffusing portion capable of suppressing the generation of light diffraction and moire fringing to an acceptable level can be manufactured in a relatively simple way.

[0071] In the transmissive screen 200 according to the second embodiment, the light diffusing portion 230 has a haze value of 60%. The light diffusing portion 230 can suppress the generation of fuzziness and defocus as well as light diffraction and moire fringing to an acceptable level.

[0072] In the transmissive screen 200 according to the second embodiment, the light diffusing portion 230 has a gloss value of 20%. The light diffusing portion 230 can suppress the generation of graininess and defocus to an acceptable level, in addition to light diffraction and moire fringing, to an acceptable level.

[0073] In the transmissive screen 200 according to the second embodiment, the resin sheet used as the light diffusing portion 230 has substantially conical irregularities on its surface. The substantially conical irregularities have a height difference of 5 to 20 μm. Therefore, the resin sheet can suppress the generation of light diffraction and moire fringing to an acceptable level in the transmissive screen 200 according to the second embodiment.

[0074] (Third Embodiment)

[0075] Fig. 6 illustrates the structure of a transmissive screen according to a third embodiment. As shown in Fig. 6, the transmissive screen 300 according to the third embodiment includes a Fresnel lens portion 310, a microlens array portion 320, a light shield member 340 having apertures near focal points of the microlenses, and a diffusing sheet 350 disposed at the light-exiting surface side of the light shield memeber 340.

[0076] In the transmissive screen 300 according to the third embodiment, the light shield member 340 can suppress the reflection of external light effectively to increase image contrast.

[0077] In addition, the diffusing sheet 350 can convert light passing through the microlenses into light having specific viewing angle characteristics.

[0078] (Fourth Embodiment)

[0079] Fig. 7 is an external view of a rear projector according to a fourth embodiment of the present invention. Fig. 8 illustrates the optical system of the rear projector according to the fourth embodiment of the present invention. Referring to Figs. 7 and 8, the rear projector 10 according to the fourth embodiment includes an optical projecting unit 20, a light-guide mirror 30, and a transmissive screen 40, which are disposed in a housing 50.

[0080] The transmissive screen 40 of the rear projector 10 is the transmissive screen 100 according to the first embodiment. Therefore, there is provided an excellent rear projector allowing a well-balanced increase in the vertical, horizontal, and oblique viewing angle characteristics for enhancing the viewing angle characteristics.

[0081] (Fifth Embodiment)

[0082] Fig. 9 illustrates the optical system of a rear projector according to a fifth embodiment of the present invention. Referring to Fig. 9, the rear projector 12 according to the fifth embodiment includes an optical projecting unit 20 and a transmissive screen 40, which are disposed in a housing 50.

[0083] The presence or absence of a light-guide mirror distinguishes the rear projector 12 according to the fifth embodiment from the rear projector 10 according to the fourth embodiment. That is, the rear projector 10 according to the fourth embodiment has the light-guide mirror 30, while the rear projector 12 according to the fifth embodiment has no light-guide mirror. The absence of a light-guide mirror eliminates image deterioration attributed to the reflection by the light-guide mirror of an image to be projected, enhancing the display quality of the image projected on the transmissive screen 40.

[0084] The transmissive screen 40 of the rear projector 12 is also the transmissive screen 100 according to the first embodiment. Therefore, there is provided an excellent rear projector allowing a well-balanced increase in the vertical, horizontal, and oblique viewing angle characteristics for enhancing the viewing angle characteristics.

[0085] The transmissive screens according to the present invention have been exemplified by the transmissive screen 100 according to the first embodiment, the transmissive screen 200 according to the second embodiment, the transmissive screen 300 according to the third embodiment, the rear projector 10 according to the fourth embodiment, and the rear projector 12 according to the fifth embodiment. However, the transmissive screens of the present invention are not limited to the above embodiments; various modifications are permitted within the scope of the present invention.